Six steps to

QNl4ar+JLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC4/OAVpDDa8KKGKV0Ymy+78= on 04/23/2020

The arterial blood gas (ABG) analysis is a lab test that measures the acid-base balance (pH) and oxygenation of an arterial blood sample, usually obtained by direct arterial puncture. For the patient in critical care requiring multiple blood draws, an arterial line should be used. Nurses can learn valuable information about their patients by analyzing the ABG results. For example, subtle changes in the pH may signal hemodynamic decompensation, and improvements in oxygen saturation may be related to improved perfusion.

Like many other lab tests, the ABG analysis is a tool to help nurses provide better care for their patients.

Measure for measure

The blood pH is a measurement of the acid content of the blood; specifically, the partial pressure of hydrogen ions in the blood. Too many hydrogen ions in the blood lower the partial pressure and decrease the pH, causing acidosis. Conversely, too few hydrogen ions increase the partial pressure and the pH level rises, causing the patient to become alkalotic.[1] Because the human body is sensitive to changes in pH, the normal range is narrow.

The ABG analysis can measure two factors that affect the pH: the partial pressure of carbon dioxide ($PaCO_2$) and bicarbonate (HCO_3) levels.[1] The $PaCO_2$ measures carbon dioxide (CO_2) in the blood; it's affected by CO_2 removal in the lungs. (Carbon dioxide is produced by body tissues as a by-product of metabolism.) Respiratory disorders like emphysema will affect the lungs' ability to remove $PaCO_2$. The $PaCO_2$ is the respiratory component of the ABG. (See Glossary of terms used in ABG analysis.)

The HCO_3 measures the bicarbonate content of the blood, and it's affected by renal production of bicarbonate. If the body produces more acid than the kidneys can buffer with bicarbonate, the patient will develop acidosis. If, on the other hand, too much bicarbonate is produced, alkalosis develops. The HCO_3 is the metabolic component of the ABG analysis.

The ABG measurement also assesses oxygenation, as mentioned earlier. The partial pressure of oxygen (PaO_2) measures the amount of oxygen dissolved in the blood. After oxygen dissolves in the blood, it attaches to hemoglobin. The number of

G analysis

Refresh your understanding of arterial blood gas measurements and what they tell you about your patient.

By David W. Woodruff, RN, CCRN, CNS, MSN

hemoglobin binding sites that have oxygen attached to them is called the oxygen saturation (SaO_2).[1] An SaO_2 of 95% means that 95% of the available hemoglobin binding sites have oxygen attached. The SaO_2 is dependent on the PaO_2. Oxygen has to first dissolve in the blood before it can bind to hemoglobin. Body temperature, hydrogen ion concentration, 2,3-diphosphoglycerate, and CO_2 levels can affect how easily oxygen attaches to hemoglobin and will, therefore, affect the SaO_2.[2] (See Oxyhemoglobin dissociation curve.)

Choosing the target

Arterial blood gas samples must be drawn from an artery that's close to the skin and has adequate redundant circulation. The radial artery is generally the preferred site because it's readily accessible and its redundant circulation comes from the ulnar artery. Care should be taken when drawing a blood sample from the wrist of a patient with carpal tunnel syndrome; the condition may make him more susceptible to risk of injury of the underlying nerves.[3]

If, for whatever reason, the radial artery can't be used to draw the blood sample, the femoral artery is the second choice. It, too, is readily accessible and has redundant circulation. The downside is that this site is more prone to infection.

The choice of last resort is the brachial artery. This vessel often lacks redundant circulation, and damage to the brachial artery

Glossary of terms used in ABG analysis

pH	Acid content of the blood
$PaCO_2$	Carbon dioxide content of the blood
PaO_2	Oxygen content of the blood
HCO_3	Bicarbonate content of the blood
SaO_2	Percentage of hemoglobin saturated with oxygen
Hypoxia	Inadequate oxygenation of the tissue
Hypoxemia	Low oxygen content in the blood
Hypercarbia	High carbon dioxide content
Acidemia	Too much acid in the blood
Alkalemia	Too many buffers in the blood
Compensation	Ability of the body to stabilize acid-base imbalances

can result in ischemia of the forearm and hand.[3]

Sampling refresher

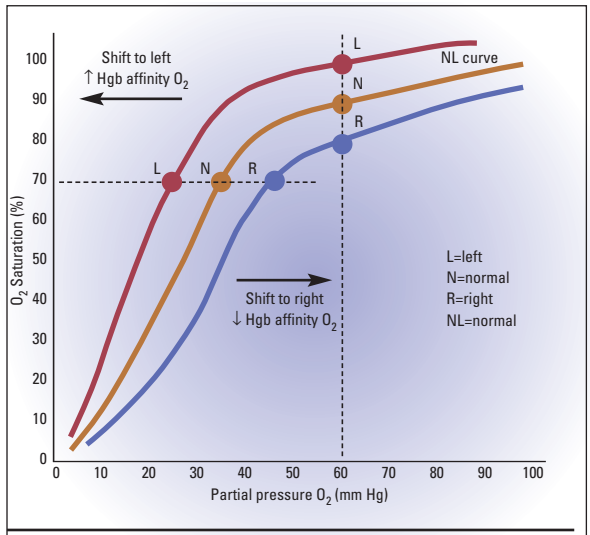
An arterial line should be used for obtaining ABGs in the patient whose condition requires multiple testing. A peripheral puncture is performed if multiple blood draws aren't necessary. Drawing an ABG sample is similar to drawing a venous blood sample. Follow your facility's policy and procedure. Perform Allen's test prior to obtaining the ABG sample. (See Allen's test.) Put on clean gloves and then prepare the site using an antimicrobial solution (such as 2% chlorhexidine gluconate or alcohol swab). Because the artery often isn't visible, you'll have to palpate it. Once you locate it, you make the puncture.

Syringes used for arterial samples are different from those used for venous samples. An arterial syringe usually has a small-bore needle attached (22-gauge or smaller), and the syringe contains heparin to prevent clotting. Once the artery is punctured, blood will start flowing into the syringe. Pressure in the arterial system usually provides a brisk, sometimes pulsatile, flow. Be careful not to introduce air bubbles into the sample because they'll alter oxygen readings.

The sampling syringe is marked to show when the required amount of blood is drawn (usually 1 to 1.5 mL). Once the correct amount of blood is drawn, the needle should be withdrawn rapidly and pressure applied immediately. If bleeding occurs at the puncture site, it may be quite brisk and could cause a hematoma or, rarely, primary compartment syndrome. Maintain pressure on the puncture site for a minimum of 5 minutes, longer if the patient has an elevated prothrombin time/activated partial thromboplastin time or if he's taking anticoagulants. Apply a pressure dressing to prevent oozing or rebleeding.

When you document the procedure, be sure to include the time the specimen was drawn, percentage of oxygen therapy, arterial puncture site, results of Allen's test, any difficulties encountered during the procedure, application of pressure, what type of dressing was used, and the patient's response.[3] Follow your facility's policy and procedure regarding the use of ice for ABG specimens.

Oxyhemoglobin dissociation curve



Adapted from: Smeltzer S, Bare B. *Brunner & Suddarth's Textbook of Medical-Surgical Nursing*. 10th ed. Philadelphia, Pa: Lippincott Williams & Wilkins; 2004.

Allen's test

The Allen's test is used to confirm redundant circulation. To perform it, occlude the radial and ulnar arteries by applying firm pressure to the inner and outer aspects of the wrist. Maintain the pressure until the hand turns pale; then release the pressure on the ulnar artery. The hand should "pink up." If the hand remains pale, insufficient redundant circulation is present and damage to the radial artery could result in ischemia of the hand. Another site should be considered to draw an ABG sample.

Six-step program

An ABG result is best analyzed by dividing it into the two major components discussed at the beginning of this article: acid-base balance and oxygenation. This process can be described by the following six steps. (See A 6-step program for ABG analysis.)

1. *Analyze the pH.* Although 7.4 is the optimal blood pH, the body will tolerate a pH from 7.35 to 7.45.[4] If the pH is lower than 7.35, the patient is acidotic; if it's higher than 7.45, he's alkalotic. If the pH is in the normal range, look to see which side of 7.4 it lies on. If the pH is 7.37, it's said to be normal lying on the acidotic side. This indicates that the patient may be acidotic, but he's compensating to make the pH closer to normal.[5]

2. *Analyze the $Paco_2$.* Remember, CO_2 is produced in the tissues of the body and eliminated

in the lungs. Changes in the $PaCO_2$ level reflect lung function. Normal $PaCO_2$ levels range from 35 to 45 mm Hg.[4] A $PaCO_2$ level below 35 mm Hg can be caused by hyperventilation—basically blowing off CO_2—which will make the patient alkalotic. When the $PaCO_2$ level rises above 45 mm Hg and the patient retains CO_2, he's said to be acidotic.

3. *Analyze the HCO_3.* Bicarbonate is produced by the kidneys and represents the metabolic component of the blood gas. Normal levels are from 22 to 26 mEq/L.[4] An HCO_3 level below 22 mEq/L indicates acidosis, and a level above 26 mEq/L indicates alkalosis.

4. *Match either the $PaCO_2$ or the HCO_3 with the pH.* If the pH is low and the $PaCO_2$ is high, the patient has respiratory acidosis. The patient has respiratory alkalosis if the pH is high and the $PaCO_2$ is low. If the pH and HCO_3 are high but the $PaCO_2$ is normal, the patient has metabolic alkalosis. The patient has metabolic acidosis if the pH and HCO_3 are low and the $PaCO_2$ is normal.

5. *Determine whether the $PaCO_2$ or the HCO_3 go in the opposite direction of the pH.* If so, then the patient has compensation. Compensation is the ability of one system to attempt to balance the pH when the other system is causing an imbalance. For example, when the respiratory system (CO_2) becomes acidotic, the metabolic system (HCO_3) will become alkalotic to attempt to bring the pH back to normal. The respiratory system can compensate within seconds, but it may take hours for the metabolic system to fully compensate.[4]

6. *Analyze the PaO_2 and SaO_2 for hypoxemia.* If the PaO_2 is less than 80 mm Hg, or the SaO_2 is less than 95%, the patient has hypoxemia. A patient on supplemental oxygen may have a PaO_2 of more than 100 mm Hg.[1]

Evaluating results

Consider three examples of ABG results and what they tell you about your patient's condition. For instance:

- pH, 7.28
- $PaCO_2$, 56 mm Hg
- PaO_2, 70 mm Hg
- HCO_3, 25 mEq/L
- SaO_2, 89%.

What do these numbers tell you about the patient? The pH is less than 7.35, indicating acidosis. The $PaCO_2$ is higher than 45 mm Hg, indicating acidosis. The $PaCO_2$ matches the pH, making it a respiratory acidosis. The HCO_3 is normal, indicating there's no compensation. The PaO_2 and SaO_2 are low, indicating hypoxemia.

The full diagnosis for a patient with these ABG results is uncompensated respiratory acidosis with hypoxemia. This patient may be suffering from pneumonia, chronic obstructive pulmonary disease (COPD), or some other primary respiratory disorder. Treatment will consist of administering oxygen to improve his oxygenation and decrease his $PaCO_2$ by improving his ventilation. That's an encyclopedia of knowledge to get out of a small amount of blood.

Another example could be:

- pH, 7.5
- $PaCO_2$, 36 mm Hg
- PaO_2, 92 mm Hg
- HCO_3, 27 mEq/L
- SaO_2, 97%.

The pH is above 7.45, indicating alkalosis. The $PaCO_2$ is normal, with no compensation. The HCO_3 is above 26 mEq/L, which is alkalotic; it matches the pH, indicating metabolic alkalosis. The PaO_2 and SaO_2 are normal. (See Normal values for ABGs.)

The full diagnosis indicated by this ABG analysis is uncompensated metabolic alkalosis. The patient is losing acid from the body, probably from vomiting or loss from a nasogastric (NG) tube. Treatment should be aimed at limiting gastrointestinal (GI) loss and giving intravenous (I.V.) fluids to replace volume and restore pH balance.[4]

And lastly:

- pH, 7.37
- $PaCO_2$, 66 mm Hg
- PaO_2, 70 mm Hg
- HCO_3, 37 mEq/L
- SaO_2, 93%.

Although the pH is normal, it's less than 7.4. So it's on the acidotic side. The $PaCO_2$ is above 45 mm Hg, which is acidotic; it matches the pH, indicating res-

A 6-step program for ABG analysis

1. Analyze the pH.
2. Analyze the $PaCO_2$.
3. Analyze the HCO_3.
4. Match either the $PaCO_2$ or the HCO_3 with the pH.
5. Does either the $PaCO_2$ or the HCO_3 go in the opposite direction of the pH?
6. Analyze the PaO_2 and SaO_2.

piratory acidosis. The HCO_3 is above 26 mEq/L, which is alkalotic; it goes the opposite direction, indicating compensation. Because the pH is adjusted back into the normal range, it's called full compensation. Both the Pa_{O_2} and the oxygen saturation are low, indicating hypoxemia.

The full diagnosis for the patient with this ABG analysis is fully compensated respiratory acidosis with hypoxemia. Compensation from the kidneys takes several hours, indicating that this problem is probably chronic.[4] Treatment will likely include oxygen administration. The Pa_{CO_2} will remain uncorrected if the problem is in fact chronic, such as in COPD. Trying to correct Pa_{CO_2} isn't advised because the patient will simply resume retaining CO_2 once treatment stops.

Acidosis vs. alkalosis

Respiratory acidosis is caused by the lungs' inability to effectively remove the CO_2 produced by metabolism.[1] It's most often caused by a pulmonary disorder, like COPD, asthma, pneumonia, or pulmonary edema. To remove the excess CO_2, the patient will have to move more air through his lungs. This can be accomplished by using bronchodilators to open up the airways or by using a bilevel positive airway pressure (BiPAP) machine or mechanical ventilation to increase tidal volume. The metabolic system compensates for respiratory acidosis by producing more HCO_3.[1] This process is slow, and full compensation by the kidneys indicates a chronic condition.

As mentioned above, *respiratory alkalosis* is caused by blowing off CO_2, usually by hyperventilation. Encourage the patient to slow his breathing. In some cases, it's helpful to have the patient breathe into a paper bag; this allows the rebreathing of CO_2. If a patient on a BiPAP machine or a ventilator develops respiratory alkalosis, his respiratory rate or tidal volume is probably set too high and needs to be adjusted. In respiratory alkalosis, the metabolic system compensates by lowering the HCO_3.

Metabolic acidosis can be brought on by a variety of conditions, ranging from kidney failure, poisoning (especially with antifreeze or aspirin overdose), diarrhea, or shock to diabetic ketoacidosis.[4] Treatment of the underlying condition should come first. If that doesn't fully resolve the acidosis, then administration of sodium bicarbonate may be appropriate. The pulmonary system compensates for metabolic acidosis by increasing the respiratory rate, thus increasing CO_2 removal.

Metabolic alkalosis can be the result of loss of acid from the stomach through vomiting or excess NG suction.[4] If vomiting can be controlled or NG suction slowed down, alkalosis may resolve spontaneously. If not, I.V. fluids are typically given for volume replacement and correction of the imbalance. The pulmonary system compensates for metabolic alkalosis by decreasing the respiratory rate and retaining CO_2.[6]

Normal values for ABGs

pH	7.35 to 7.45
Pa_{CO_2}	35 to 45 mm Hg
Pa_{O_2}	80 to 100 mm Hg
HCO_3	22 to 26 mEq/L
Sa_{O_2}	95 to 100%

Note: These are normal values at sea level.

Further steps

If no compensation is found in the blood gas analysis, the problem is likely to be acute; the patient's acid-base imbalance may cause respiratory, cardiac, or GI dysfunction. Treatment goals include managing the underlying disorder to correct the pH.

If, on the other hand, compensation is indicated by the test results, the disorder may be chronic and the acid-base imbalance may persist despite treatment. Instruct the patient on how to manage the underlying disorder so the imbalance doesn't become worse. ❖

REFERENCES

1. Guyton AC, Hall JE. Regulation of acid-base balance. In: *Textbook of Medical Physiology,* 10th ed. Philadelphia, Pa: W.B. Saunders; 2000.

2. Varjavand N, et al. The interactive oxyhemoglobin dissociation curve. Available at: http://www.ventworld.com/resources/oxydisso/dissoc.html. Accessed December 4, 2006.

3. Bucher L. Arterial puncture. In: Lynn-McHale Wiegand DJ, Carlson KK, eds. *AACN Procedure Manual for Critical Care*, 5th ed. Philadelphia, Pa: Elsevier Saunders; 2005.

4. Dufour DR. *Clinical Use of Laboratory Data.* Philadelphia, Pa: Lippincott Williams & Wilkins; 1998.

5. Woodruff D. Take these 6 easy steps to ABG analysis. *Nurs Made Inc Easy!* 2006;4 (1):4-7.

6. Martin L. *All You Really Need to Know to Interpret Arterial Blood Gases,* 2nd ed. Philadelphia, Pa: Lippincott Williams & Wilkins; 1999.

David W. Woodruff is president, Ed4Nurses.com, Macedonia, Ohio.